Coupled Contaminant Transport Processes in the Vadose Zone

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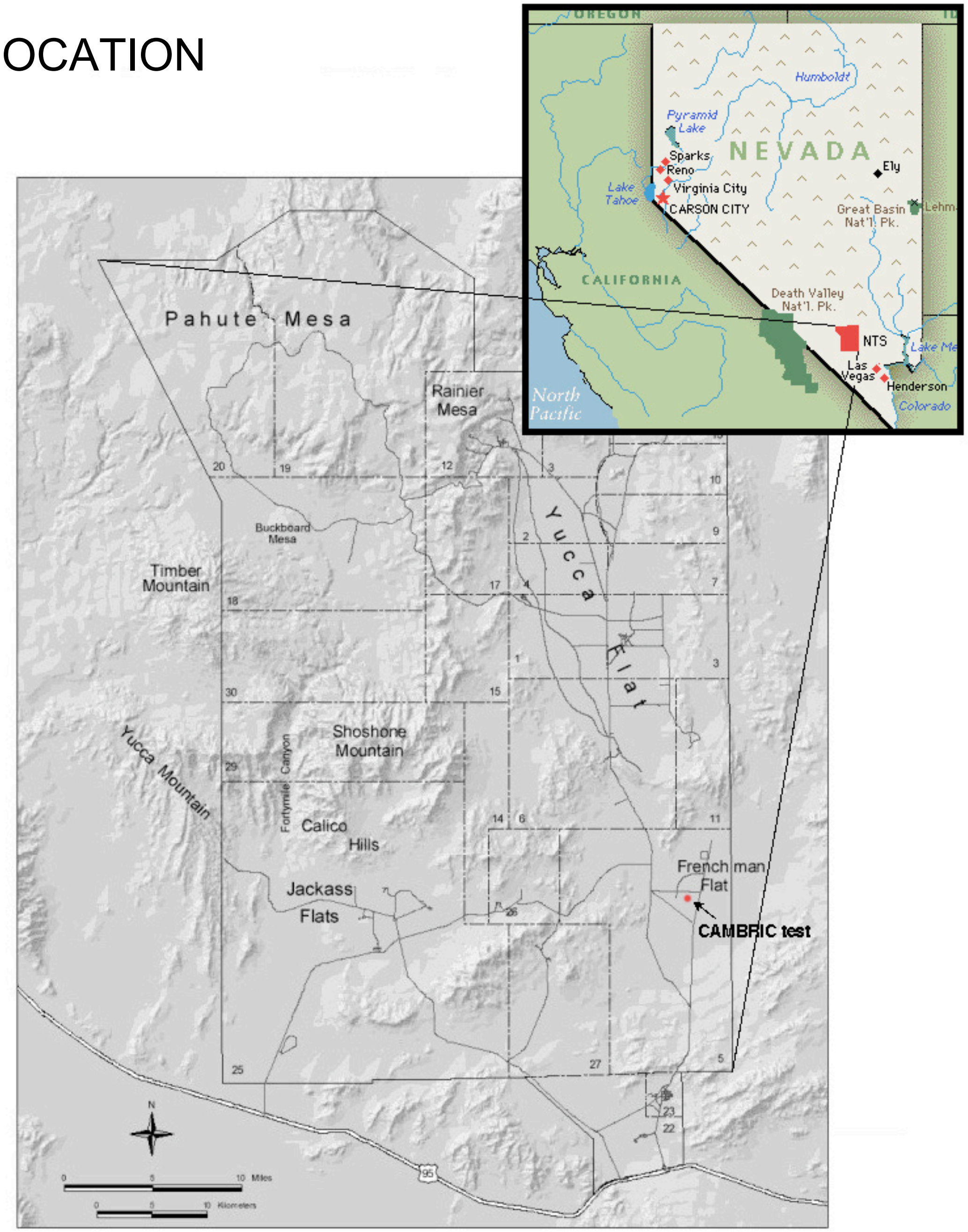
Outline:

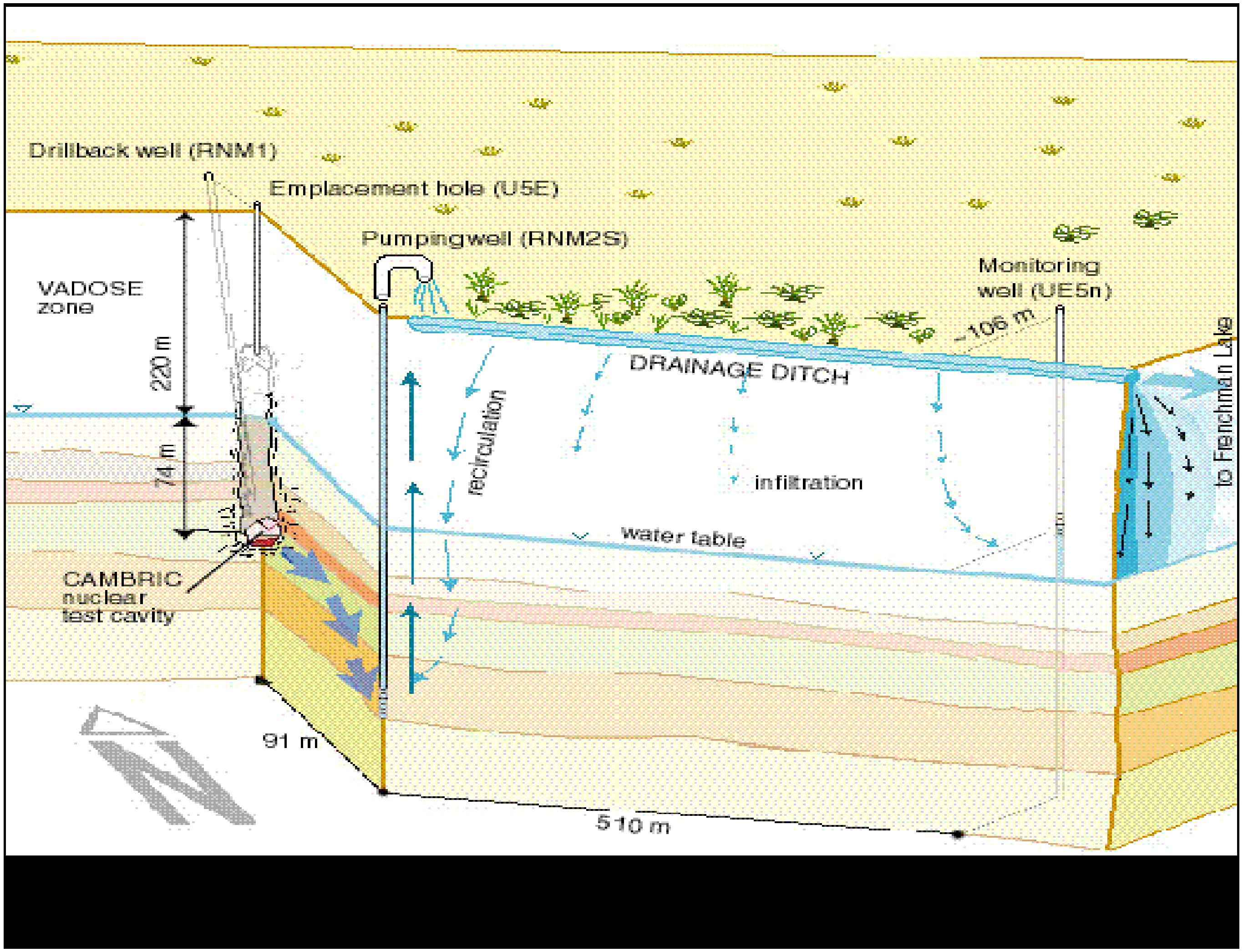
- Tritium and ^{85}Kr at the Nevada Test Site
  - Groundwater/Vadose Zone Coupling
  - Vadose Zone/Atmosphere Coupling
- Tritium at Lawrence Berkeley National Laboratory
- Coupled Research for Coupled Processes

Acronym: TREES
(Terrestrial Resource Energy Extraction System)

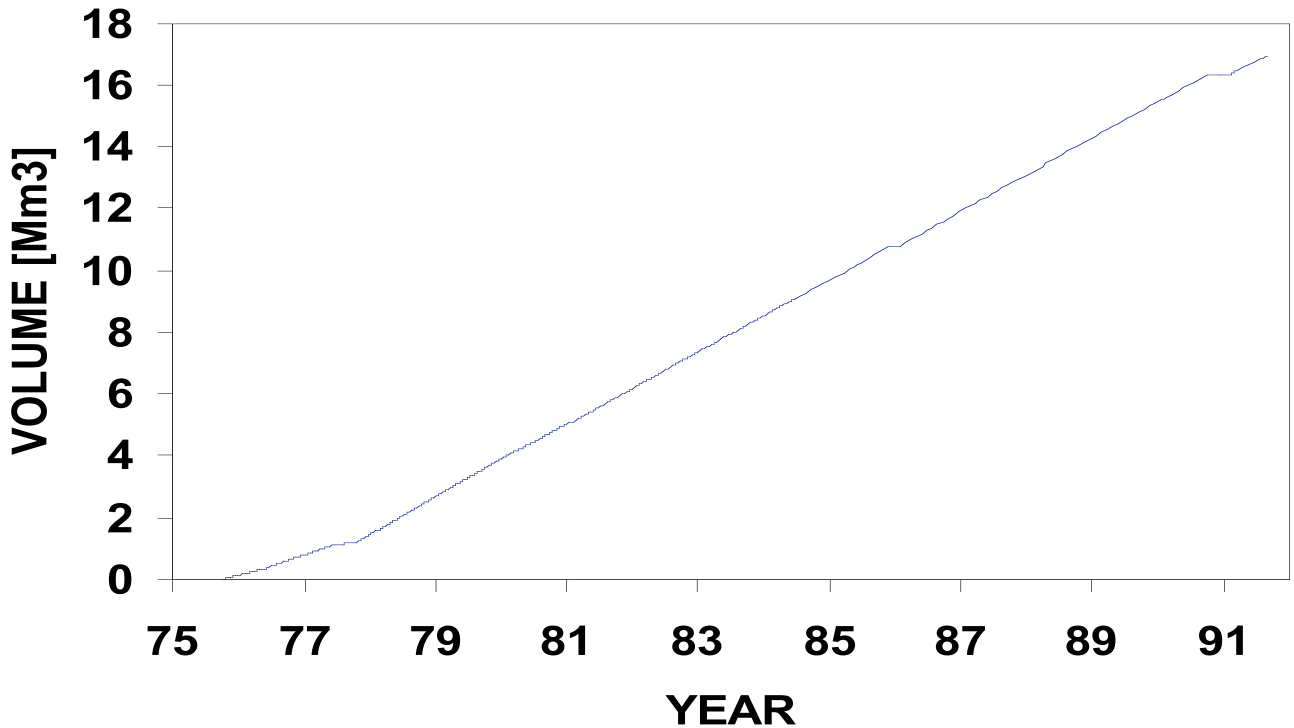
SITE LOCATION



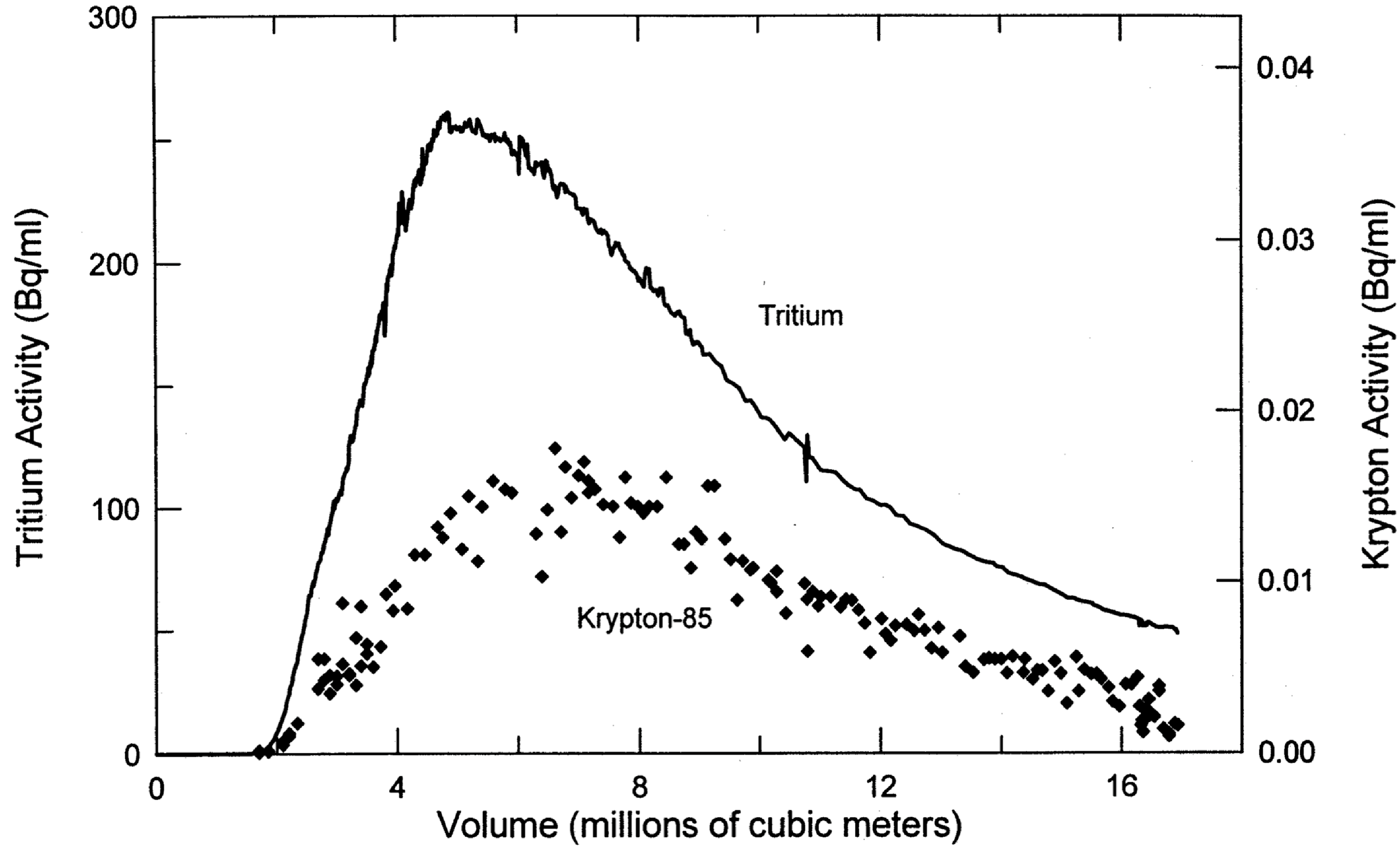
Cambric Cross Section



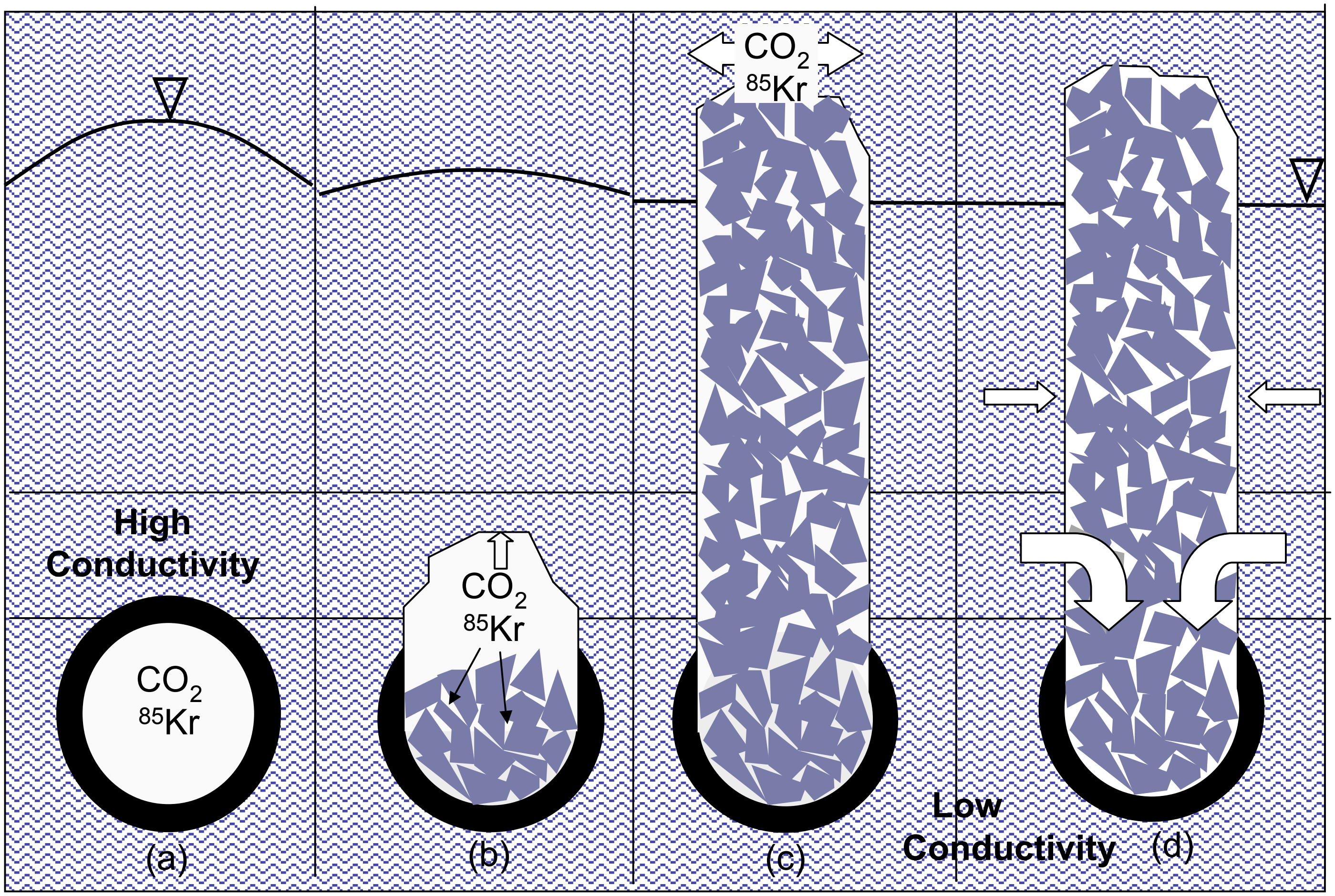
Cumulative Water Volume Pumped



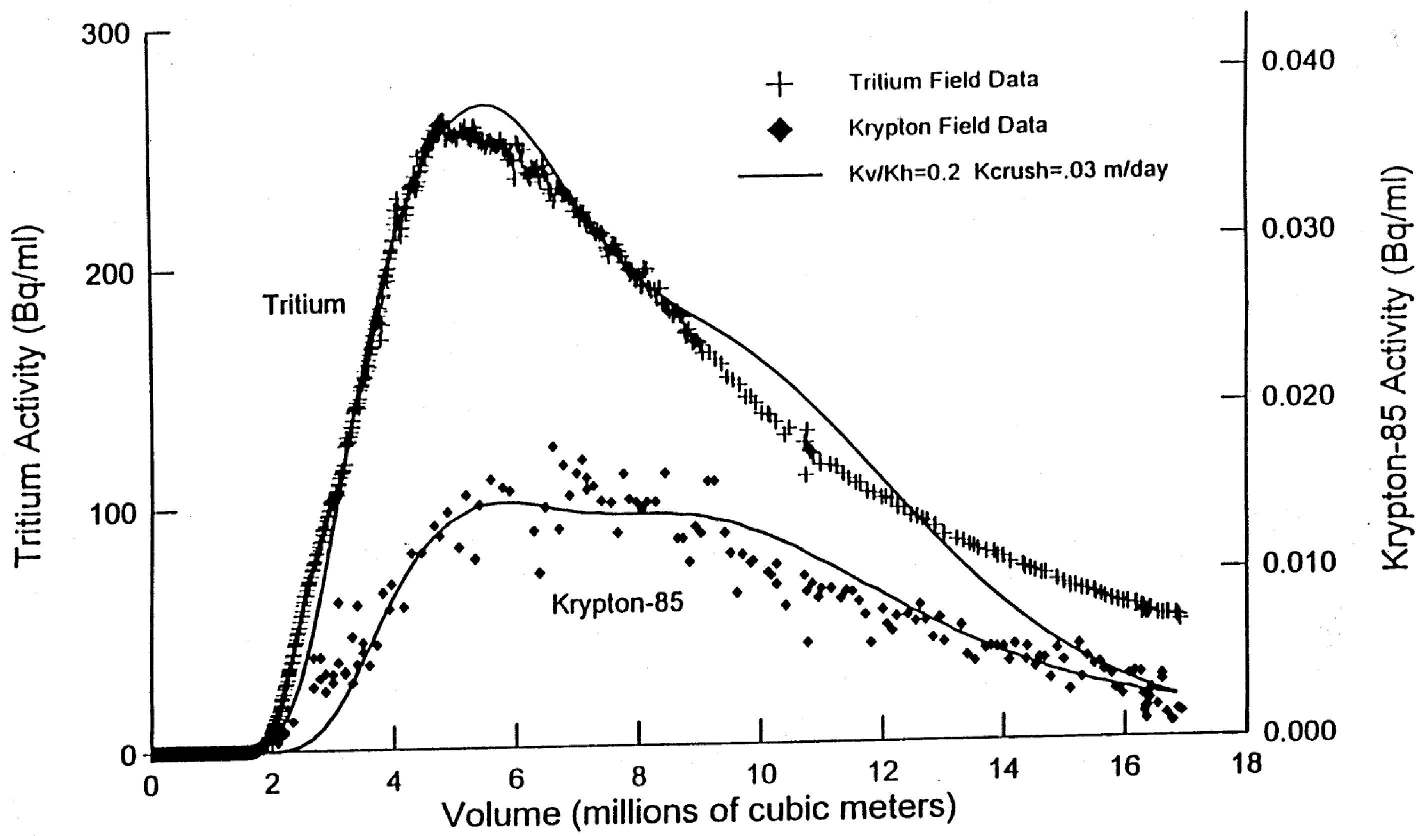
Breakthrough of Tritium and ^{85}Kr at Cambric



^{85}Kr Emplacement at Cambric

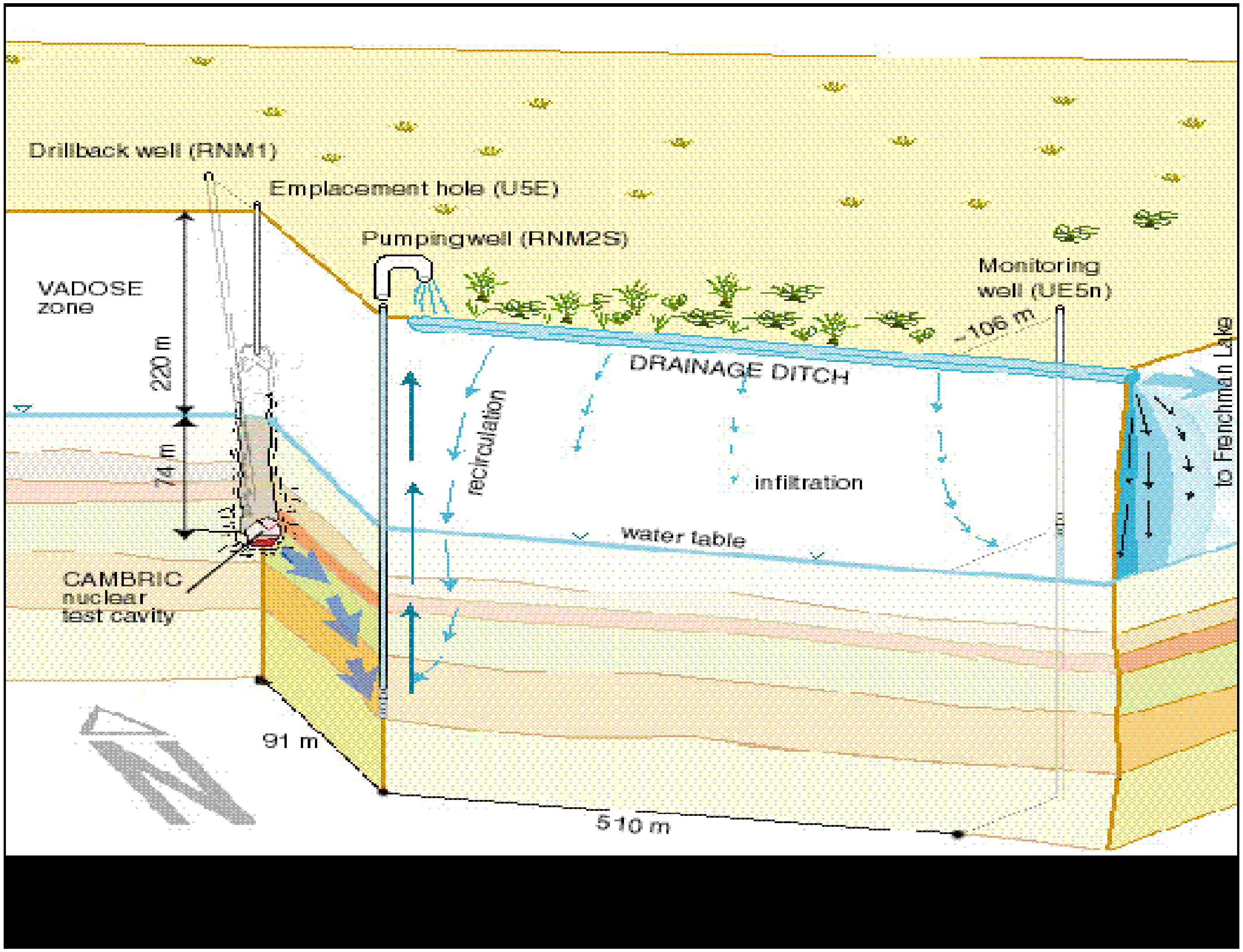


Predicted ^{85}Kr Breakthrough at Cambric



Guell and Hunt, July 2003, WRR

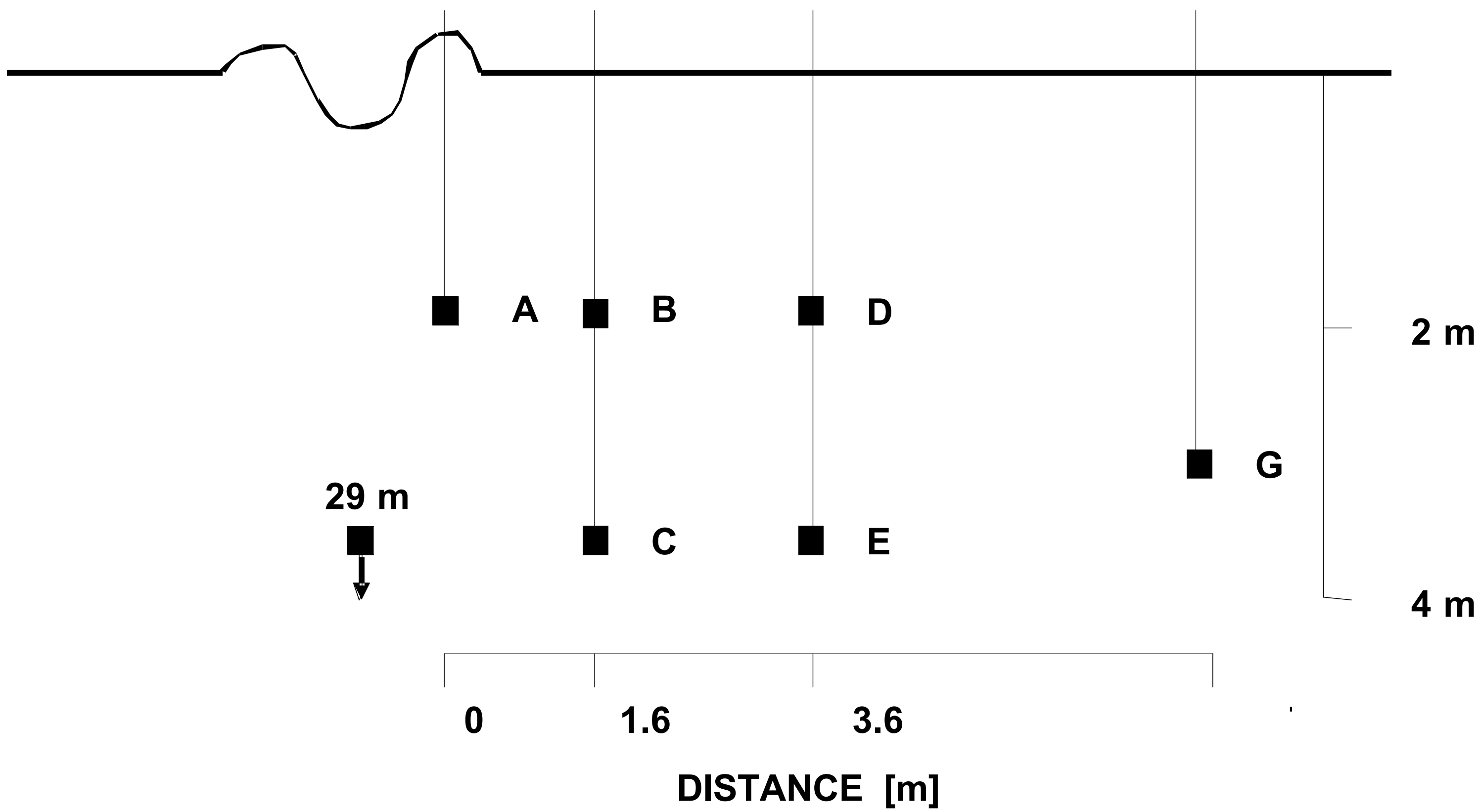
Cambric Cross Section



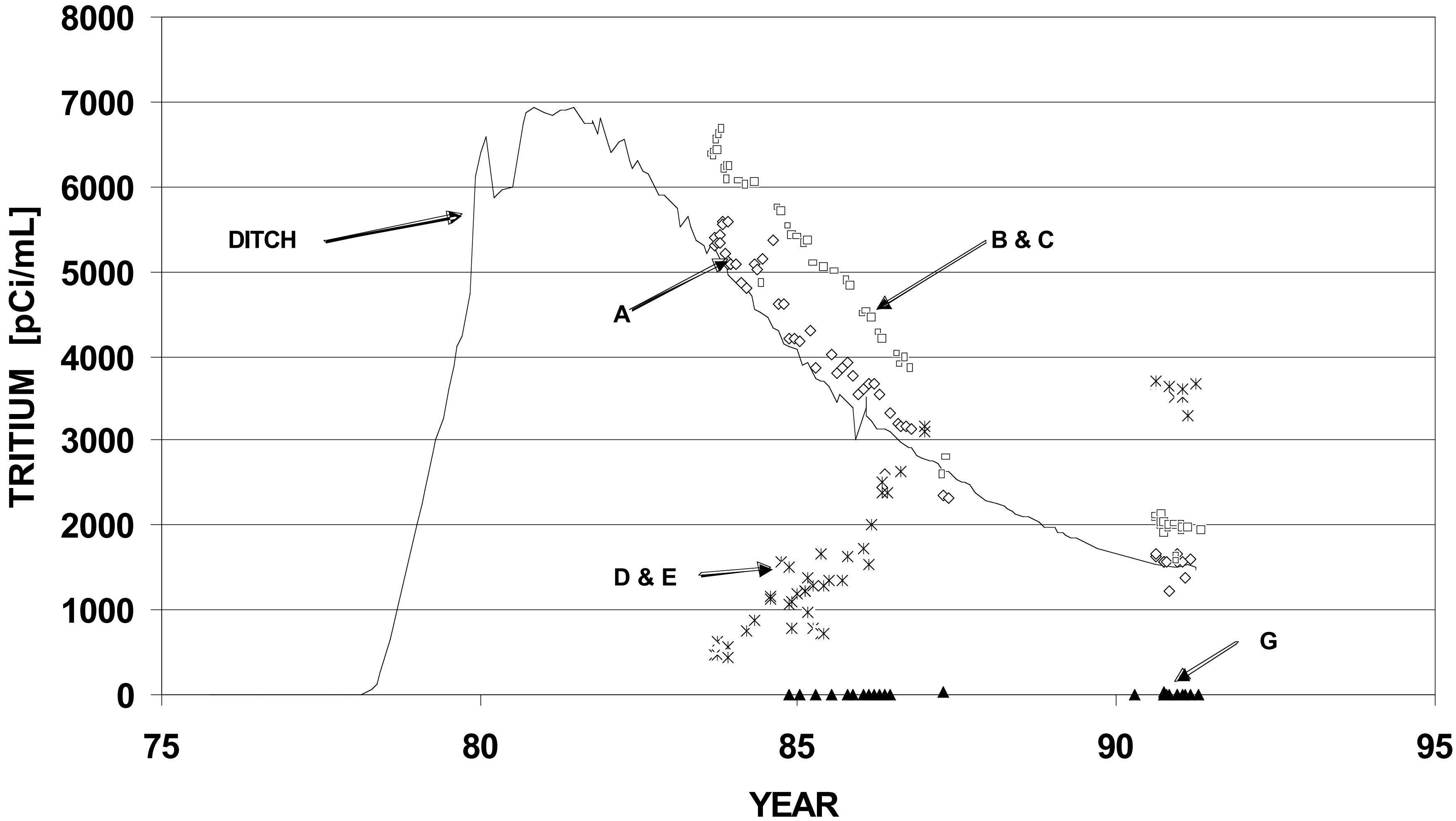
Cambric Ditch, Summer 2002

Cambric Ditch Lysimeters

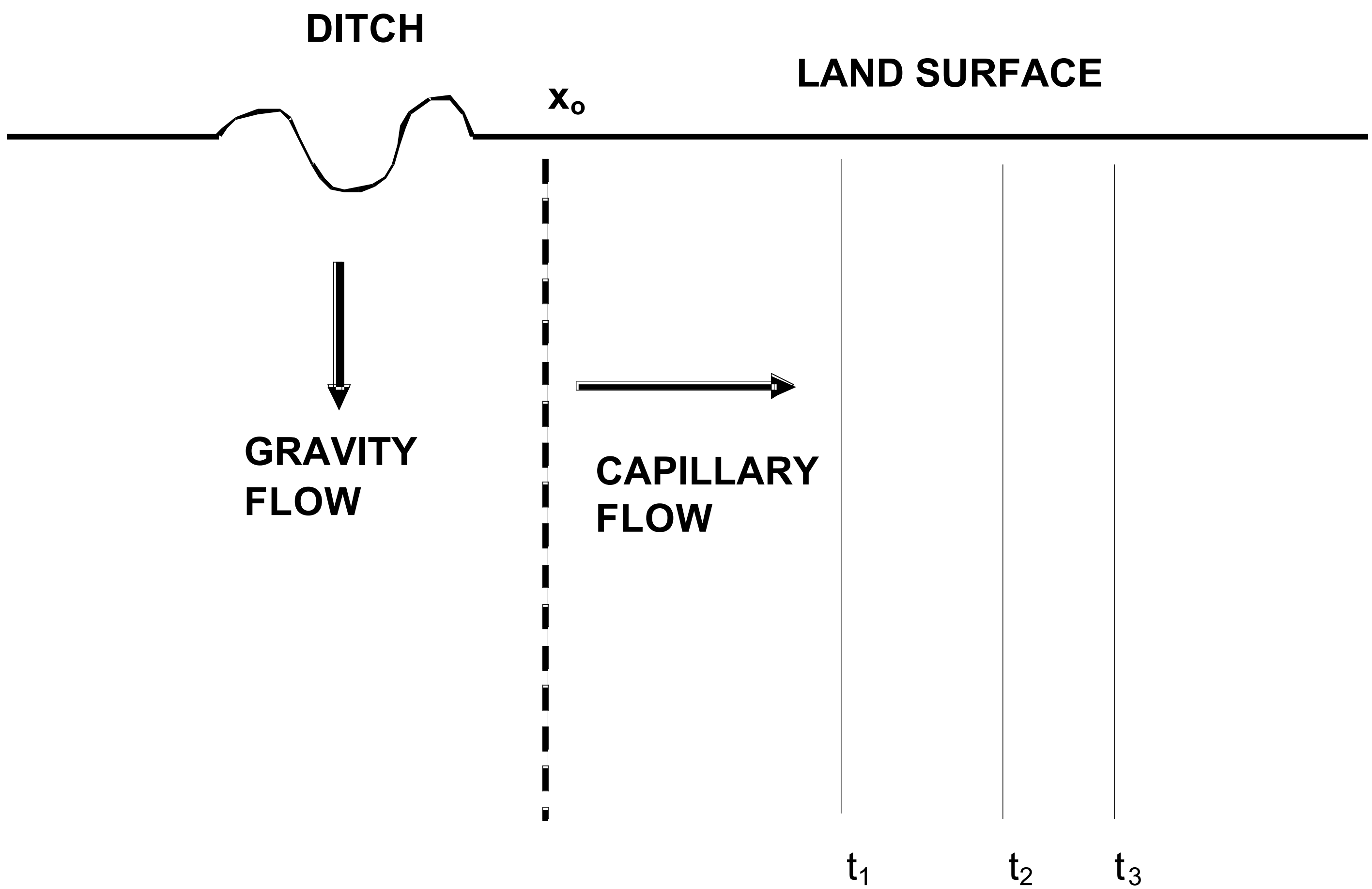
LYSIMETER LOCATIONS



CAMBRIC LYSIMETERS



WETTING FRONT MIGRATION



UNSATURATED FLOW MODELING

NONSTEADY - HORIZONTAL FLOW

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left[D(\theta) \frac{\partial \theta}{\partial x} \right] \qquad D(\theta) = K(h)\frac{\partial h}{\partial \theta}$$

PARTIAL SOLUTION FOR SEMI-INFINITE MEDIUM

$$\theta(x, t) = \theta(x t^{-1/2})$$

WETTING FRONT LOCATION $\quad L_f(t) = \lambda_f t^{1/2}$

TRANSFORMATION OF CAMBRIC DATA

WETTING FRONT LOCATION $L_f(t) = \lambda_f t^{1/2}$

WETTING FRONT VELOCITY $v_f(t) = \frac{1}{2}\lambda_f t^{-1/2}$

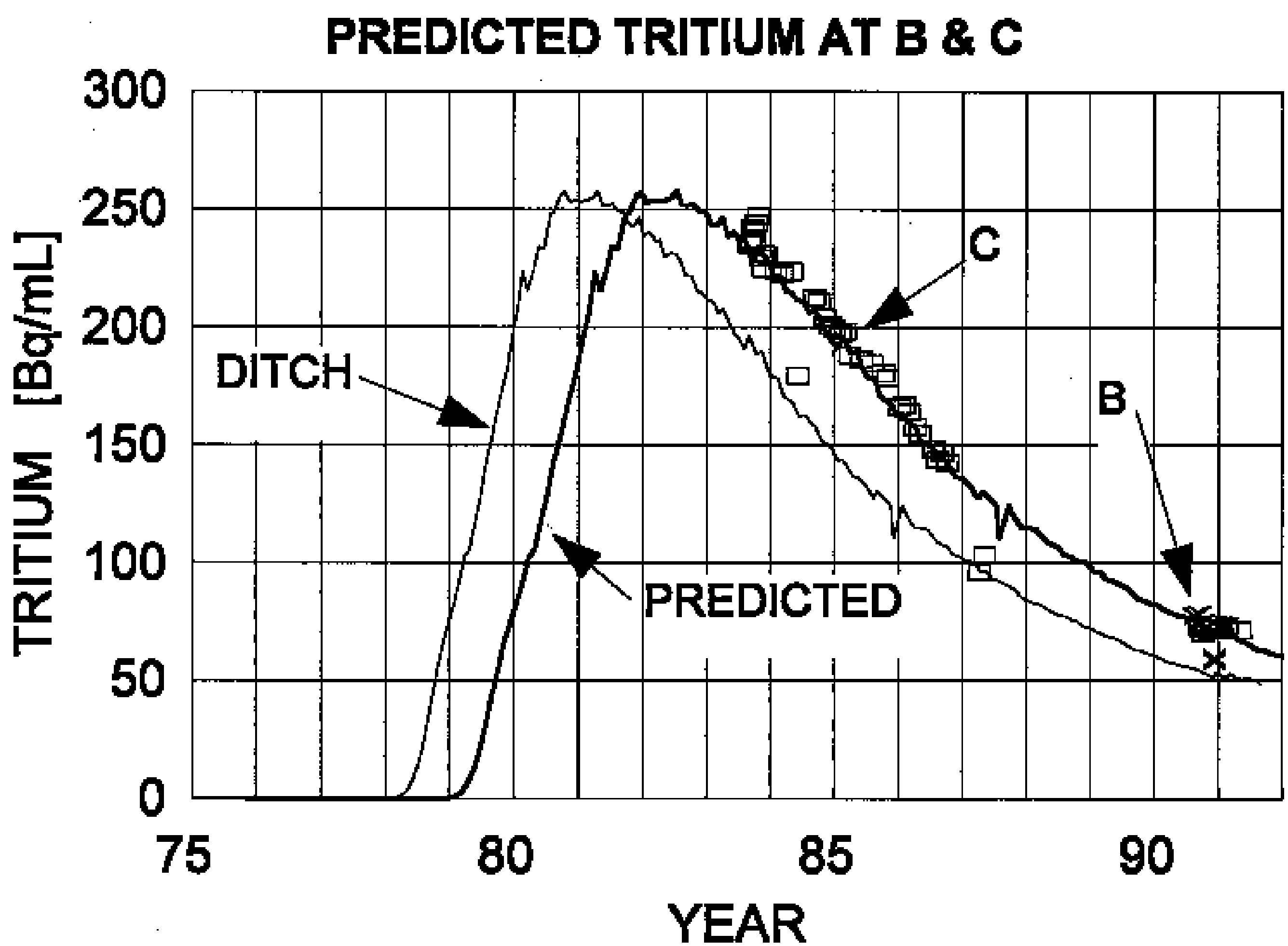
TRITIUM ARRIVING AT *(X, T)* LEFT THE DITCH AT TIME T_d

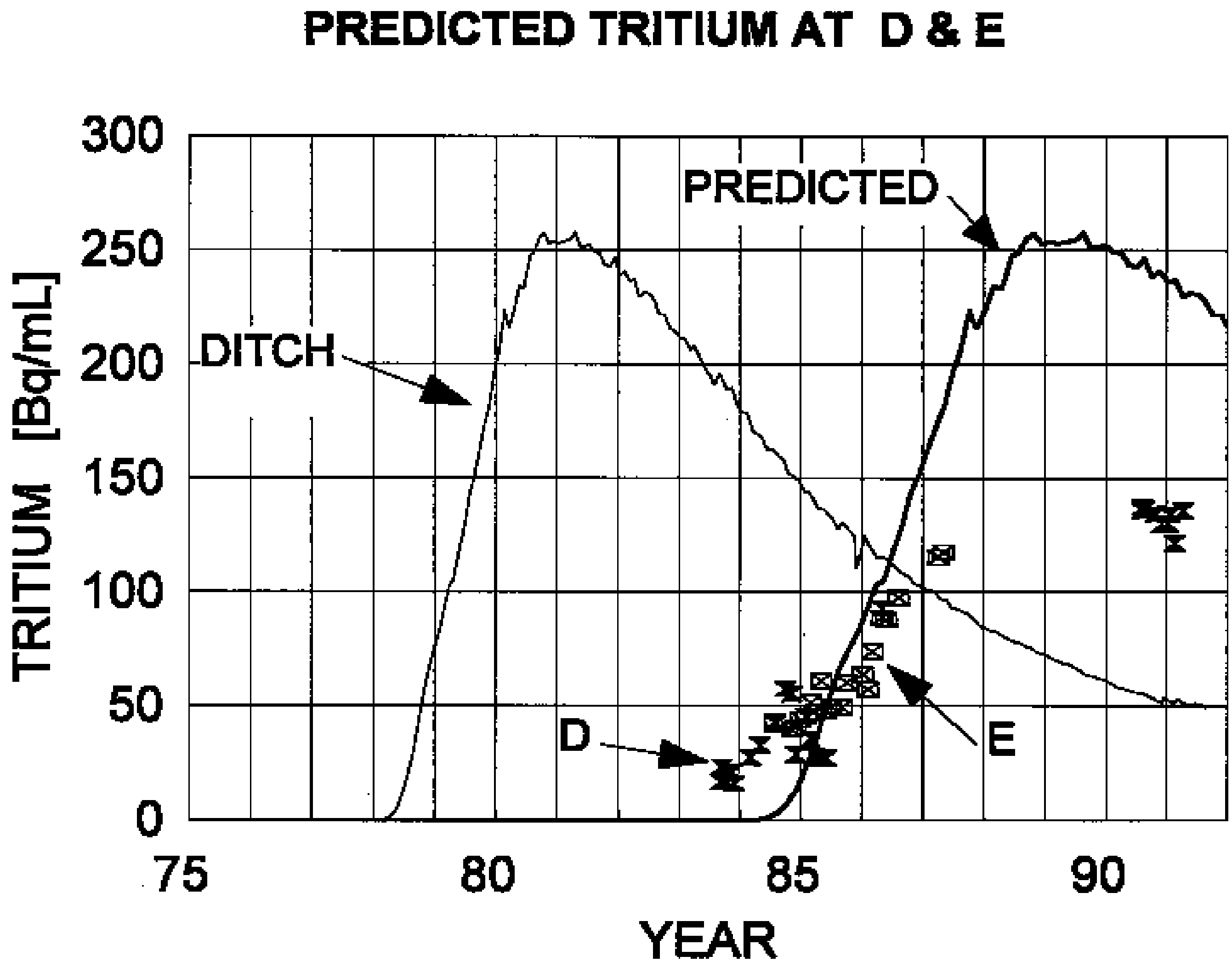
$$\int_{X_o}^{X} dx = \int_{T_d}^{T} v_f(t)\,dt$$

SOLVING FOR T_d

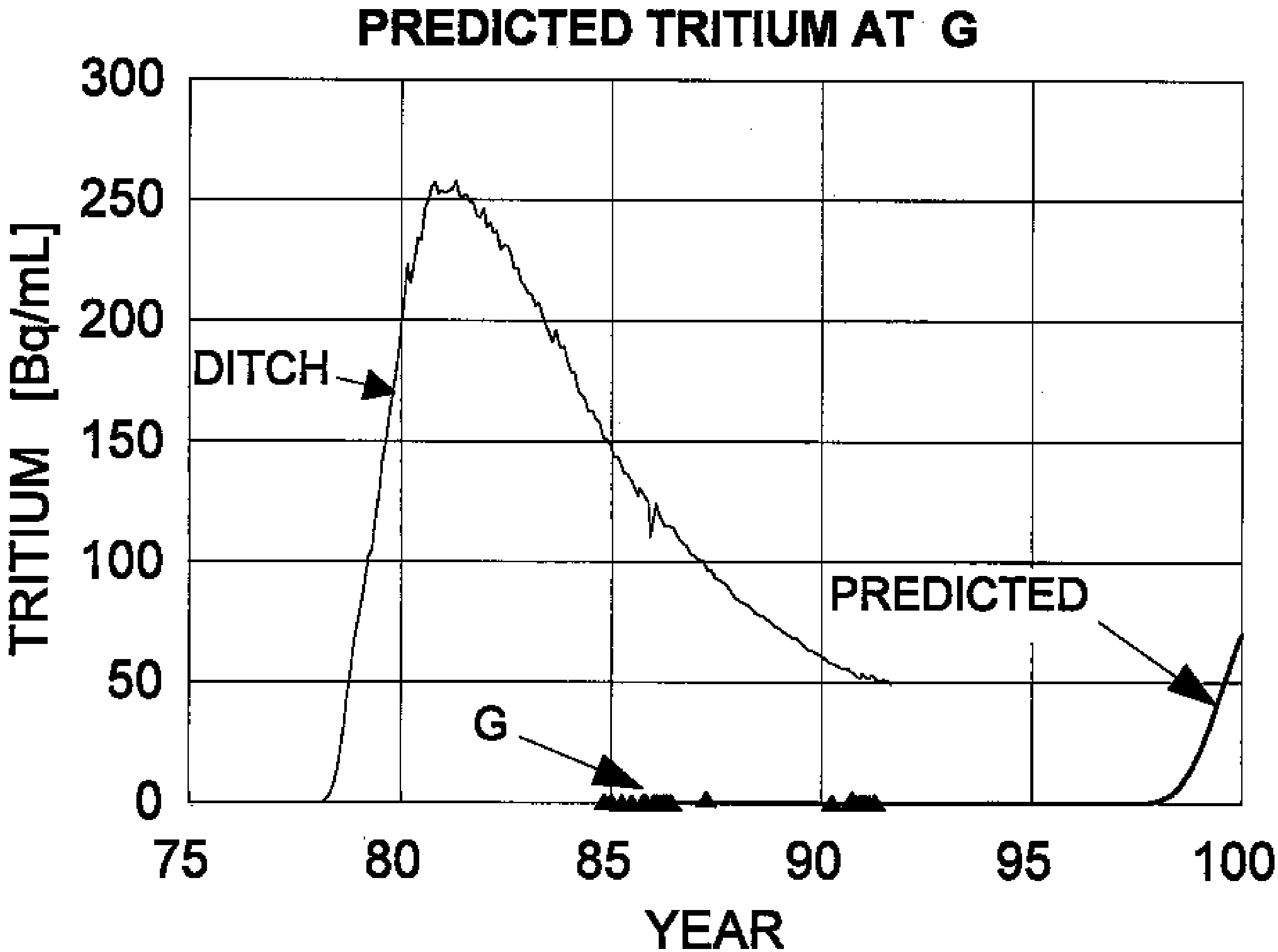
$$T_d = \left(T^{1/2} - \frac{X - X_o}{\lambda_f} \right)^2$$

FOUND $X_0 = 1.1$ m AND $\lambda_f = 1.7$ m yr$^{-1/2}$

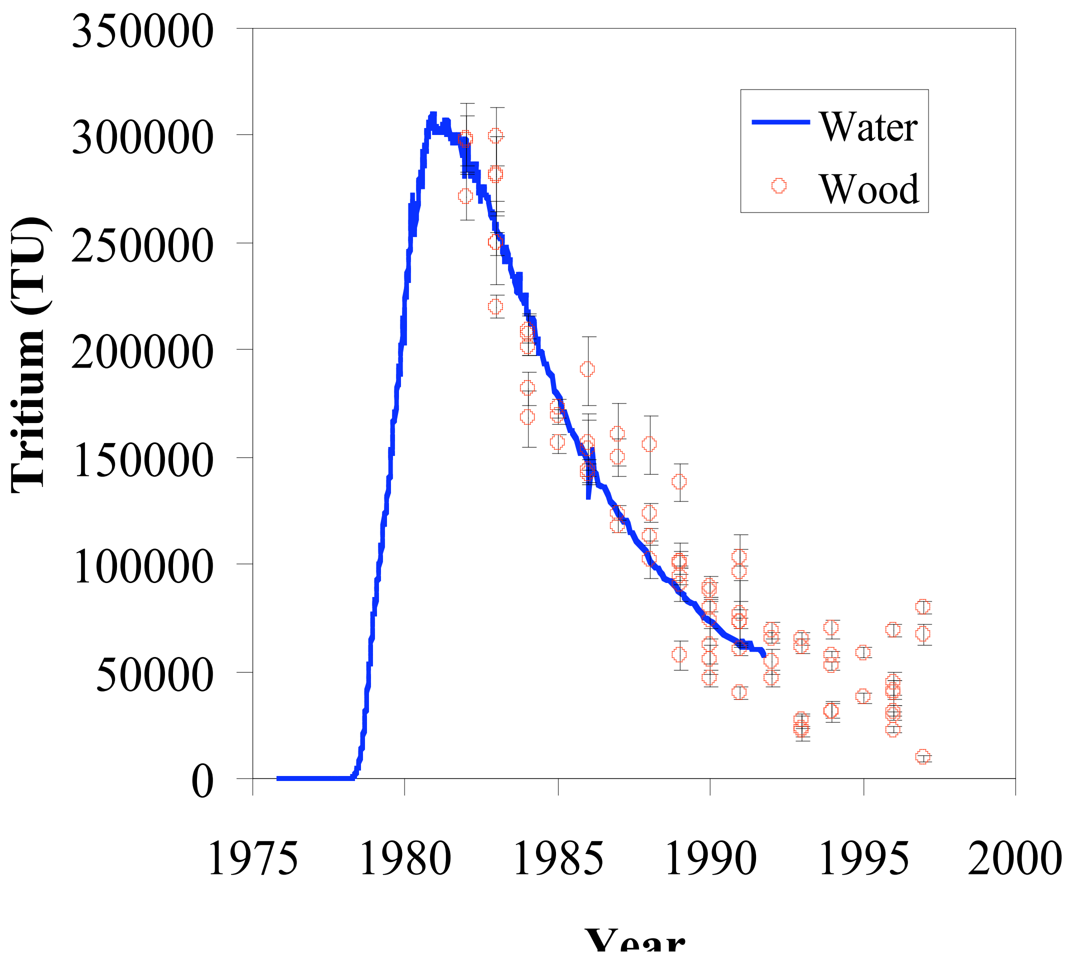

PREDICTED TRITIUM AT B & C
TRITIUM [Bq/mL]
300
250
200
150
100
50
0
75
80
85
90
YEAR
DITCH
PREDICTED
C
B



PREDICTED TRITIUM AT D & E
PREDICTED
DITCH
D
E
TRITIUM [Bq/mL]
300
250
200
150
100
50
0
75
80
85
90
YEAR


PREDICTED TRITIUM AT G
TRITIUM [Bq/mL]
300
250
200
150
100
50
0
75
80
85
90
95
100
YEAR
DITCH
PREDICTED
G

Cambric Ditch Tree Ring Analysis for Tritium by AMS



Love et al., ES&T, 2002

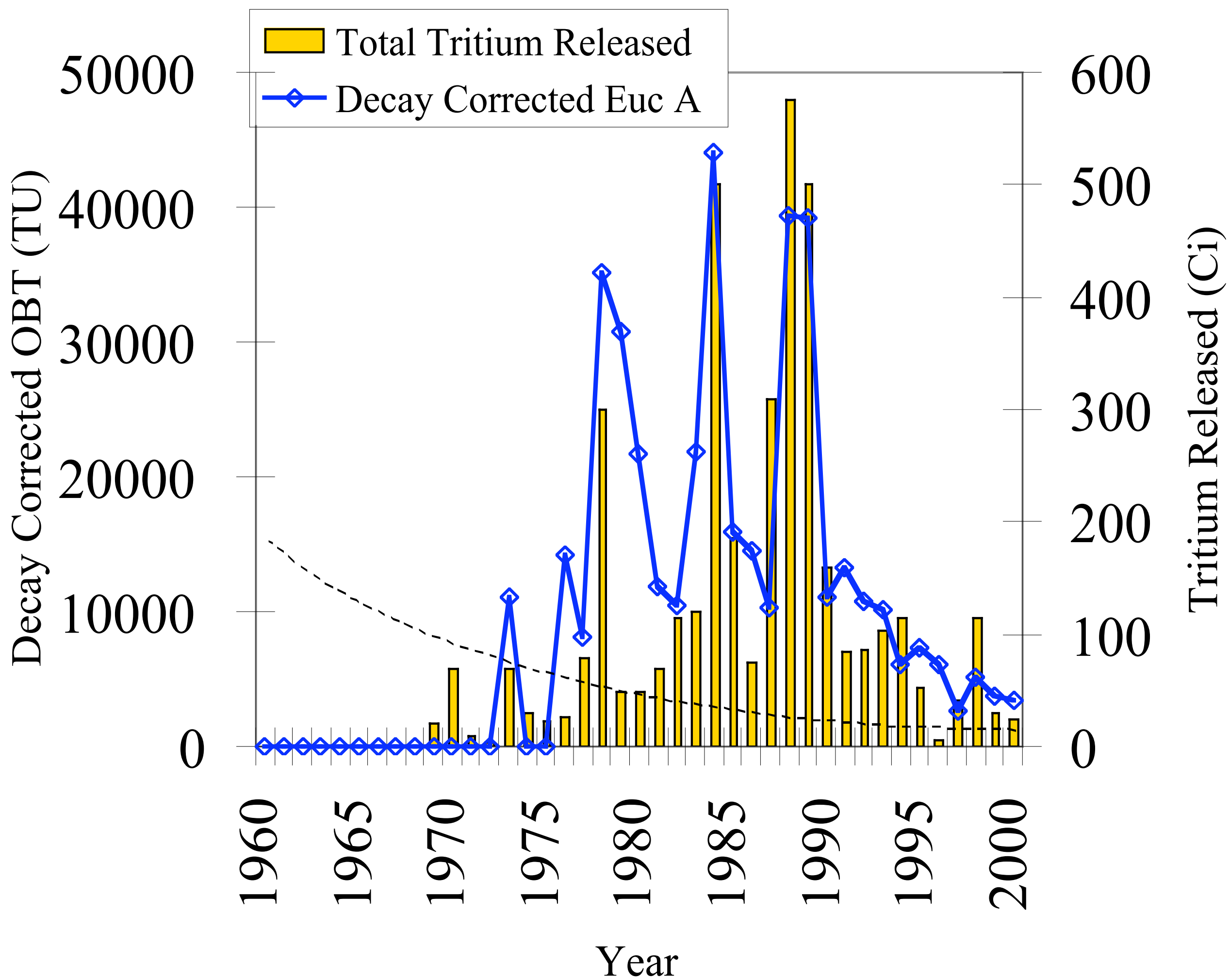
LBNL: National Tritium Labeling Facility

•Tritiated water vapor discharged for 30+ years

•Trees grew around atmospheric discharge stack

•Reported release data from 1969-2000 was compared to tree rings collected in 2001

Tritium Reconstruction from Tree Ring Analysis
LBNL: National Tritium Labeling Facility



Love et al., ES&T, in press

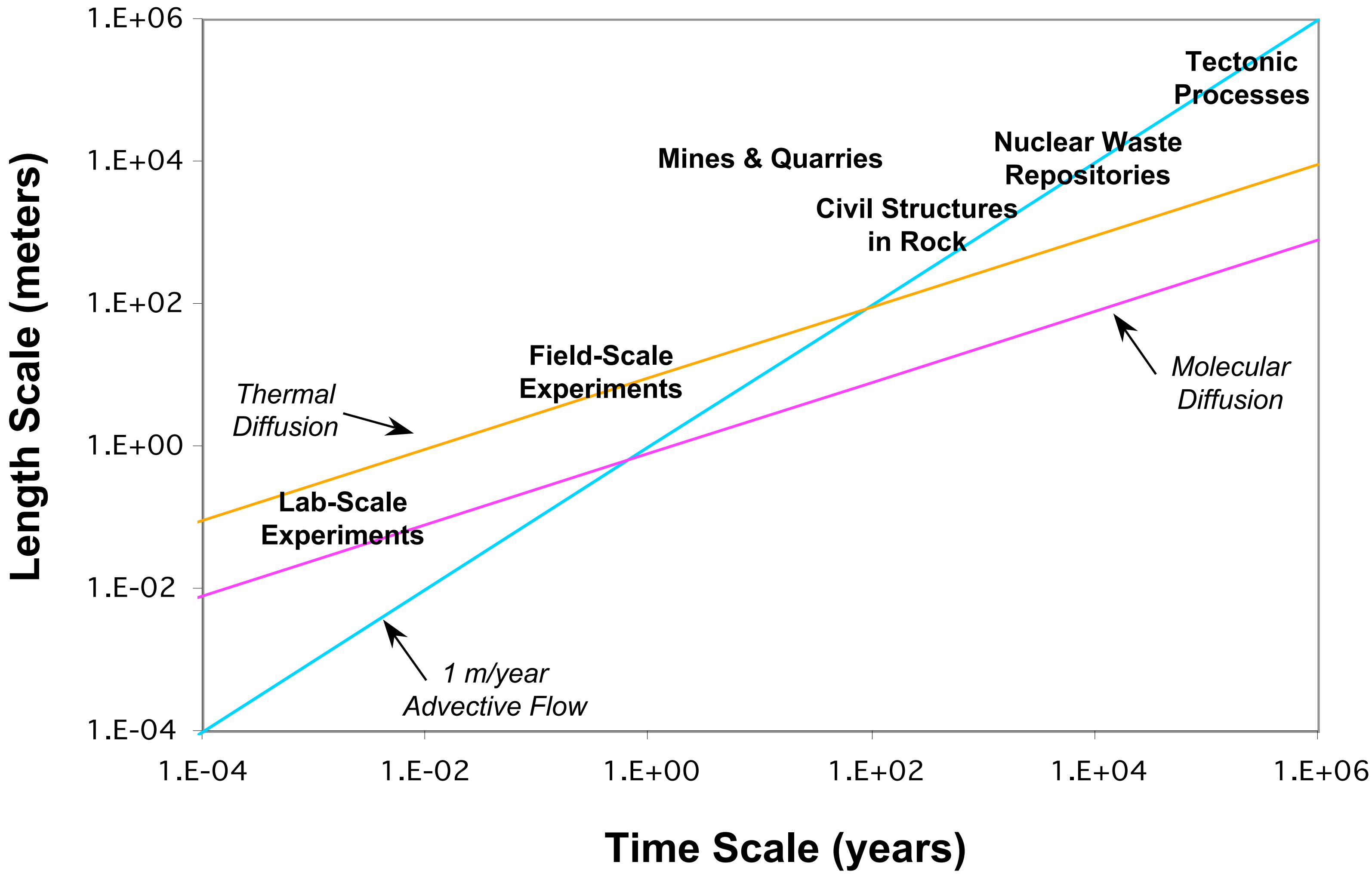
LBNL: Predicting Tritium Exposure?

Number of Papers in Recent Literature that Addressed Coupled Thermal, Mechanical, Hydrologic and Chemical Processes

Modeling or Analysis \ Experimental Data	No Experimental Data Sets	Data for Single Process	Two Coupled Processes	Three Coupled Processes	Four Coupled Processes
Four Processes					
Three Processes	10	3	2	3	
Two Processes	13	5	12	1	
Single Process		3	1	1	
No Modeling		2	5	6	

Yow and Hunt (2002)

Typical Temporal and Spatial Scales of Experiments, Engineered Structures, and Natural Phenomena



Yow and Hunt (2002).

Common Themes

- Field Data are Essential
  - Length scale of 100's of meters
  - Time scale of 10's of years
  - Need to take advantage of analog sites

- Measurements vs. Models
  - Ideally both needed
  - At the Nevada Test Site:
    - data plus model verified transport of ^{85}Kr
    - for vadose zone, model could be fit to data, but parameter was wrong
  - At LBNL: results solely dependent upon data from advanced instrumentation

Thanks:
Margaret Guell, ^{85}Kr at Cambric
Cindy Kao, Wetting Fronts at Cambric
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Dr. Andy Tompson, photographer